

In the Claims:

Please cancel claims 2-4, 7-8, 62, 65-66, 74, 76, and 78-79. Please amend claims 1, 5-6, 12, 18, 20, 22, 25, 28-29, 31-32, 34-37, 41-42, 47, 50, 57, 63, and 69-70. Please add new claims 80-91.

1. (Currently amended) A solder composition, comprising a solder alloy,
wherein the alloy is substantially free of lead,
wherein the alloy includes tin (Sn), silver (Ag), and copper (Cu), and bismuth (Bi).
wherein the tin has a weight percent concentration in the alloy of at least about 90%,
wherein the silver has a weight percent concentration of X in the alloy,
wherein X is sufficiently small that formation of Ag₃Sn plates is substantially suppressed
when the alloy in a liquefied state is being solidified by being cooled at to a lower temperature at
which the solid Sn phase is nucleated,
wherein the lower temperature corresponds to an undercooling δT relative to the eutectic
melting temperature of the alloy, and
wherein the copper has a weight percent concentration in the alloy not exceeding about
1.5%, and
wherein the bismuth has a weight percent concentration in the alloy from 0.1% to about
0.2%.

2-4. (Canceled)

10/078,020

2

5. (Currently amended) The composition of claim 1, wherein the copper weight percent concentration in the liquefied alloy is sufficiently small that the pasty range of the liquefied alloy does not exceed about 10 °C the weight percent concentration of the tin in the alloy is in a range of 90% to 95%.

6. (Currently amended) The composition of claim 1, wherein the copper weight percent concentration in the liquefied alloy does not exceed about 0.9%.

7-8. (Canceled)

9. (Original) The composition of claim 1, wherein X does not exceed about 2.8%.

10. (Original) The composition of claim 1, wherein X is in a range of about 2.6% to about 2.8%.

11. (Original) A method for forming an electrical structure, comprising:

providing a first substrate and a first solder ball attached to a first electrically conductive pad that is coupled to the first substrate, wherein the first solder ball comprises a solder alloy, wherein the alloy is substantially free of lead, wherein the alloy includes tin (Sn), silver (Ag), and copper (Cu), wherein the tin has a weight percent concentration in the alloy of at least about 90%, and wherein the copper has a weight percent concentration in the alloy not exceeding about 1.5%;

providing a second substrate and a second electrically conductive pad coupled to

the second substrate;

coupling the first solder ball to the second pad;

melting the first solder ball by heating the first solder ball to form a modified solder ball;

and

solidifying the modified solder ball by cooling the modified solder ball to a lower temperature at which the solid Sn phase is nucleated, and wherein the lower temperature corresponds to an undercooling δT relative to the eutectic melting temperature of the alloy, wherein the solidified modified solder ball is a solder joint that couples the first substrate to the second substrate, and wherein a silver weight percent concentration X_2 in the modified solder ball is sufficiently small that formation of Ag_3Sn plates is substantially suppressed during said cooling.

12. (Currently amended) The method of claim 11, wherein ~~providing the first substrate and the first solder ball comprises selecting a silver weight percent concentration X_1 in the alloy of the first solder ball such that X_2 is sufficiently small that said formation of the Ag_3Sn plates is substantially suppressed during said cooling~~ the alloy further includes antimony at a weight percent sufficient to suppress tin pest formation in the solidified modified solder ball.

13. (Original) The method of claim 11, wherein X_2 does not exceed X_{MAX} , wherein X_{MAX} is the maximum silver weight percent concentration in the modified solder ball at which Ag_3Sn plates are thermodynamically barred from being formed in the modified solder ball during said cooling.

14. (Original) The method of claim 13, further comprising determining X_{MAX} as a function of δT from a ternary phase diagram and associated thermodynamic data relating to a ternary mixture of Sn, Ag, and Cu.

15. (Original) The method of claim 11, wherein the first substrate comprises a chip carrier, and wherein the second substrate comprises a circuit card.

16. (Original) The method of claim 15, wherein the first solder ball is a ball grid array (BGA) solder ball.

17. (Original) The method of claim 11, wherein the first substrate comprises a chip, and wherein the second substrate comprises a chip carrier.

18. (Currently amended) The method of claim 11, wherein X_2 is in a range of about 2.6% to about 2.8% said cooling the modified solder ball is at a cooling rate in a range of about 1.2 °C/sec to about 3.0 °C/sec.

19. (Original) The method of claim 11, wherein X_2 does not exceed about 2.8%.

20. (Currently amended) The method of claim ~~11~~ 18, wherein the copper weight percent concentration in the modified solder ball during cooling is sufficiently small that the pasty range of the modified solder ball during cooling does not exceed about 10 °C wherein X_2 does not

exceed about 2.8%.

21. (Original) The method of claim 11, wherein the copper weight percent concentration in the modified solder ball does not exceed about 0.9%.

22. (Currently amended) The method of claim 11, wherein the ~~second pad is a copper pad~~ weight percent concentration of the tin in the alloy is in a range of 90% to 95%.

23. (Original) The method of claim 11, wherein the second pad is a copper pad, and wherein the copper weight percent concentration in the first solder ball does not exceed about 0.5%.

24. (Original) The method of claim 11, wherein the second pad is a nickel-gold pad.

25. (Currently amended) The method of claim 11, wherein the alloy further includes a substance ~~that suppresses tin pest formation in the alloy~~ bismuth, and wherein the bismuth has a weight percent concentration in the alloy from 0.1% to about 0.2%.

26. (Original) The method of claim 11, wherein coupling the first solder ball to the second pad comprises applying a flux to the second pad and placing the first solder ball in contact with the flux.

27. (Original) The method of claim 11,

10/078,020

6

wherein coupling the first solder ball to the second pad comprises applying a solder paste to the second pad and placing the first solder ball in contact with the solder paste, and

wherein melting the first solder ball comprises melting the first solder ball and the solder paste by heating the first solder ball and the solder paste, such that the melted solder paste is incorporated into the melted first solder ball to form the modified solder ball, and such that the modified solder ball includes the solder paste within the first solder ball.

28. (Currently amended) The method of claim 27, wherein the solder paste includes a weight percent silver X_p that exceeds the silver weight percent concentration X_1 in the alloy of the first solder ball, and wherein $[[X_2]] X_p - X_1$ is at least 0.2%.

29. (Currently amended) A method for forming a solder composition, comprising:

providing a solder alloy, wherein the alloy is substantially free of lead, wherein the alloy includes tin (Sn), silver (Ag), and copper (Cu), wherein the tin has a weight percent concentration in the alloy of at least about 90%, wherein the silver has a weight percent concentration in the alloy not exceeding about 4.0%, and wherein the copper has a weight percent concentration in the alloy not exceeding about 1.5%;

melting the alloy by heating the alloy; and

solidifying the melted alloy by cooling the melted alloy at a cooling rate ~~that is high enough to substantially suppress Ag₃Sn plate formation in the alloy during said cooling~~ in a range of about 1.2 °C/sec to about 3.0 °C/sec.

30. (Original) The method of claim 29, further comprising, prior to said solidifying, selecting the cooling rate that is high enough to substantially suppress said Ag_3Sn plate formation in the alloy.

31. (Currently amended) The method of claim 29, wherein the cooling rate is at least about $1.2^\circ\text{C}/\text{sec}$ weight percent concentration of the silver in the alloy does not exceed about 2.8%.

32. (Currently amended) The method of claim 29, wherein the ~~copper weight percent~~ concentration in the melted alloy is sufficiently small that the ~~pasty range of the melted alloy~~ does not exceed about 10°C weight percent concentration of the tin in the alloy is in a range of 90% to 95%

33. (Original) The method of claim 29, wherein the copper weight percent concentration in the melted alloy does not exceed about 0.9%.

34. (Currently amended) The method of claim 29, wherein the alloy further includes ~~a substance~~ that antimony at a weight percent sufficient to suppress[[es]] tin pest formation in the solidified alloy.

35. (Currently amended) The method of claim ~~34~~ 29, wherein the ~~substance~~ alloy further comprises bismuth, and wherein the bismuth has a weight percent concentration ~~of at least 0.1%~~ in the alloy from 0.1% to about 0.2%.

36. (Currently amended) A method for forming an electrical structure, comprising:

providing a first substrate and a first solder ball attached to a first electrically conductive pad that is coupled to the first substrate, wherein the first solder ball comprises a solder alloy, wherein the alloy is substantially free of lead, wherein the alloy includes tin (Sn), silver (Ag), and copper (Cu), wherein the tin has a weight percent concentration in the alloy of at least about 90%, wherein the silver has a weight percent concentration in the alloy not exceeding about 4.0%, and wherein the copper has a weight percent concentration in the alloy not exceeding about 1.5%;

providing a second substrate and a second electrically conductive pad coupled to the second substrate;

coupling the first solder ball to the second pad;

melting the first solder ball by heating the first solder ball to form a modified solder ball;

and

solidifying the modified solder ball by cooling the modified solder ball at a cooling rate that is high enough to substantially suppress Ag₃Sn plate formation in the modified solder ball during said cooling, wherein the solidified modified solder ball is a solder joint that couples the first substrate to the second substrate in a range of about 1.2 °C/sec to about 3.0 °C/sec.

37. (Currently amended) The method of claim 36, further comprising, prior to said solidifying, selecting the cooling rate that is high enough to substantially suppress said Ag₃Sn plate formation in the modified solder ball wherein the alloy further comprises bismuth at a weight percent concentration in the alloy from 0.1% to about 0.2.

38. (Original) The method of claim 36, wherein the first substrate comprises a chip carrier, and wherein the second substrate comprises a circuit card.

39. (Original) The method of claim 38, wherein the first solder ball is a ball grid array (BGA) solder ball.

40. (Original) The method of claim 36, wherein the first substrate comprises a chip, and wherein the second substrate comprises a chip carrier.

41. (Currently amended) The method of claim 36, wherein the cooling rate is at least about 1-2 °C/sec weight percent concentration of the silver in the alloy does not exceed about 2.8%.

42. (Currently amended) The method of claim 36, wherein the ~~copper weight percent~~ concentration in the alloy is sufficiently small that the ~~pasty range of the alloy does not exceed~~ about 10 °C weight percent concentration of the tin in the alloy is in a range of 90% to 95%.

43. (Original) The method of claim 36, wherein the copper weight percent concentration in the alloy does not exceed about 0.9%.

44. (Original) The method of claim 36, wherein the second pad is a copper pad.

45. (Original) The method of claim 36, wherein the second pad is a copper pad, and wherein the

copper weight percent concentration in the first solder ball does not exceed about 0.5%.

46. (Original) The method of claim 36, wherein the second pad is a nickel-gold pad.

47. (Currently amended) The method of claim 36, wherein the alloy further includes a substance that antimony at a weight percent sufficient to suppress[[es]] tin pest formation in the alloy modified solder ball.

48. (Original) The method of claim 36, wherein coupling the first solder ball to the second pad comprises applying a flux to the second pad and placing the first solder ball in contact with the flux.

49. (Original) The method of claim 36,

wherein coupling the first solder ball to the second pad comprises applying a solder paste to the second pad and placing the first solder ball in contact with the solder paste, and

wherein melting the first solder ball comprises melting the first solder ball and the solder paste by heating the first solder ball and the solder paste, such that the melted solder paste is incorporated into the melted first solder ball to form the modified solder ball, and such that the modified solder ball includes the solder paste within the first solder ball.

50. (Currently amended) A pre-soldering electrical structure, comprising:

a first substrate and a first solder ball attached to a first electrically conductive pad that is

coupled to the first substrate, wherein the first solder ball comprises a solder alloy, wherein the alloy is substantially free of lead, wherein the alloy includes tin (Sn), silver (Ag), and copper (Cu), and bismuth (Bi), wherein the tin has a weight percent concentration in the alloy of at least about 90%, and wherein the copper has a weight percent concentration in the alloy not exceeding about 1.5%, and wherein the bismuth has a weight percent concentration in the alloy from 0.1% to about 0.2%;

a second substrate and a second electrically conductive pad coupled to the second substrate, wherein the first solder ball is coupled to the second pad, wherein the first solder ball is adapted to being melted by being heated to form a modified solder ball, wherein the modified solder ball is adapted to being solidified by being cooled to a lower temperature at which the solid Sn phase is nucleated, wherein the lower temperature corresponds to an undercooling δT relative to the eutectic melting temperature of the alloy, wherein the solidified modified solder ball is a solder joint that couples the first substrate to the second substrate, and wherein a silver weight percent concentration X_2 in the modified solder ball is sufficiently small that formation of Ag_3Sn plates are substantially suppressed during said cooling.

51. (Original) The electrical structure of claim 50, wherein the alloy of the first solder ball has a silver weight percent concentration X_1 , and wherein X_1 has a predetermined value based on X_2 being sufficiently small that formation of said Ag_3Sn plates is substantially suppressed during cooling of said modified solder ball.

52. (Original) The electrical structure of claim 50, wherein X_2 does not exceed X_{MAX} , wherein

X_{MAX} is the maximum silver weight percent concentration in the modified solder ball at which Ag_3Sn plates are thermodynamically barred from being formed in the modified solder ball during said cooling.

53. (Original) The electrical structure of claim 52, wherein X_{MAX} is a function of δT , said function being derived from a ternary phase diagram and associated thermodynamic data relating to a ternary mixture of Sn, Ag, and Cu.

54. (Original) The electrical structure of claim 50, wherein the first substrate comprises a chip carrier, and wherein the second substrate comprises a circuit card.

55. (Original) The electrical structure of claim 54, wherein the first solder ball is a ball grid array (BGA) solder ball.

56. (Original) The electrical structure of claim 50, wherein the first substrate comprises a chip, and wherein the second substrate comprises a chip carrier.

57. (Currently amended) The electrical structure of claim 50, wherein ~~X_2 is in a range of about 2.6% to about 2.8%~~ the weight percent concentration of the tin in the alloy is in a range of 90% to 95%.

58. (Original) The electrical structure of claim 50, wherein X_2 does not exceed about 2.8%.

59. (Original) The electrical structure of claim 50, wherein the solder paste includes a weight percent silver X_2 that exceeds X_1 , wherein X_1 is the weight percent silver in the first solder ball, and wherein $X_2 - X_1$ is at least 0.2%.

60. (Original) The electrical structure of claim 50, wherein the copper weight percent concentration in the modified solder ball during cooling is sufficiently small that the pasty range of the modified solder ball during cooling does not exceed about 10 °C.

61. (Original) The electrical structure of claim 50, wherein the copper weight percent concentration in the modified solder ball does not exceed about 0.9%.

62. (Canceled)

63. (Currently amended) The electrical structure of claim ~~62~~ 50, wherein the second pad is a copper pad, and wherein the copper weight percent concentration in the first solder ball does not exceed about 0.5%.

64. (Original) The electrical structure of claim 50, wherein the second pad is a nickel-gold pad.

65-66. (Canceled)

67. (Original) The electrical structure of claim 50, wherein the first solder ball is coupled to the

second pad by a flux that is applied to the second pad such that the first solder ball in contact with the flux.

68. (Original) The electrical structure of claim 50,

wherein the first solder ball is coupled to the second pad by a solder paste that is applied to the second pad such that the first solder ball in contact with the solder paste; and

wherein the first solder ball is adapted to being melted by heating the first solder ball and the solder paste, such that the melted solder paste is incorporated into the melted first solder ball to form the modified solder ball, and such that the modified solder ball includes the solder paste within the first solder ball.

69. (Currently amended) A post-soldering electrical structure comprising:

a first substrate; and

a second substrate, wherein the first substrate is coupled to the second substrate by a solder joint, wherein the solder joint comprises an alloy, wherein the alloy is substantially free of lead, wherein the alloy includes tin (Sn), silver (Ag), and copper (Cu), and bismuth (Bi), wherein the tin has a weight percent concentration in the alloy of at least about 90%, wherein the silver has a weight percent concentration in the alloy of X_2 , wherein X_2 is sufficiently small that Ag_3Sn plates are substantially absent in the solder joint, and wherein the copper has a weight percent concentration in the alloy not exceeding about 1.5%, and wherein the bismuth has a weight percent concentration in the alloy from 0.1% to about 0.2%.

70. (Currently amended) The electrical structure of claim 69, wherein the solder joint is formed from a first solder ball having a tin-silver-copper composition in which the silver has a weight percent concentration X_1 , wherein X_1 has a predetermined value based on X_2 being sufficiently small that said Ag₃Sn plates are substantially absent in the solder joint the weight percent concentration of the tin in the alloy is in a range of 90% to 95%.

71. (Original) The electrical structure of claim 69, wherein the first substrate comprises a chip carrier, and wherein the second substrate comprises a circuit card.

72. (Original) The electrical structure of claim 71 wherein the solder joint includes a ball grid array (BGA) solder ball.

73. (Original) The electrical structure of claim 69, wherein the first substrate comprises a chip, and wherein the second substrate comprises a chip carrier.

74. (Canceled)

75. (Original) The electrical structure of claim 69, wherein X_2 does not exceed about 2.8%.

76. (Canceled)

77. (Original) The electrical structure of claim 69, wherein the copper weight percent

concentration in the solder joint does not exceed about 0.9%.

78-79, (Canceled)

80. (New) A solder composition, comprising a solder alloy,

wherein the alloy is substantially free of lead,

wherein the alloy includes tin (Sn), silver (Ag), and copper (Cu);

wherein the tin has a weight percent concentration in the alloy in a range of 90% to 95%,

wherein the silver has a weight percent concentration in the alloy not exceeding about

2.8%,

wherein the lower temperature corresponds to an undercooling δT relative to the eutectic melting temperature of the alloy, and

wherein the copper has a weight percent concentration in the alloy not exceeding about 1.5%.

81. (New) The solder composition of claim 80, wherein the alloy further includes bismuth at a weight percent concentration in the alloy from 0.1% to about 0.2%.

82. (New) The solder composition of claim 80, wherein the alloy further includes antimony at a weight percent sufficient to suppress tin pest formation in the alloy during a subsequent cooling of the alloy.

10/078,020

17

83. (New) The composition of claim 1, wherein the copper weight percent concentration in the alloy does not exceed about 0.9%.

84. (New) A method for forming a solder composition, comprising:

providing a solder alloy, wherein the alloy is substantially free of lead, wherein the alloy includes tin (Sn), silver (Ag), and copper (Cu), wherein the tin has a weight percent concentration in the alloy in a range of 90% to 95%, wherein the silver has a weight percent concentration in the alloy not exceeding about 4.0%, and wherein the copper has a weight percent concentration in the alloy not exceeding about 1.5%;

melting the alloy by heating the alloy; and

solidifying the melted alloy by cooling the melted alloy at a cooling rate that is high enough to substantially suppress Ag_3Sn plate formation in the alloy during said cooling.

85. (New) The method of claim 84, wherein the cooling rate is at least 1.2 °C/sec.

86. (New) The method of claim 84, wherein the cooling rate is in a range of about 1.2 °C/sec to about 3.0 °C/sec.85.

87. (New) The method of claim 84, wherein the weight percent concentration of silver in the alloy does not exceed about 2.8%.

88. (New) A method for forming a solder composition, comprising:

10/078,020

18

providing a solder alloy, wherein the alloy is substantially free of lead, wherein the alloy includes tin (Sn), silver (Ag), and copper (Cu), wherein the tin has a weight percent concentration in the alloy in a range of 90% to 95%, wherein the silver has a weight percent concentration in the alloy not exceeding about 2.8%, and wherein the copper has a weight percent concentration in the alloy not exceeding about 1.5%;

melting the alloy by heating the alloy; and

solidifying the melted alloy by cooling the melted alloy at a cooling rate.

89. (New) The method of claim 88, wherein the cooling rate is at least 1.2 °C/sec.

90. (New) The method of claim 88, wherein the cooling rate is in a range of about 1.2 °C/sec to about 3.0 °C/sec.

91. (New) The method of claim 88, wherein the alloy further includes bismuth at a weight percent concentration in the alloy from 0.1% to about 0.2%.